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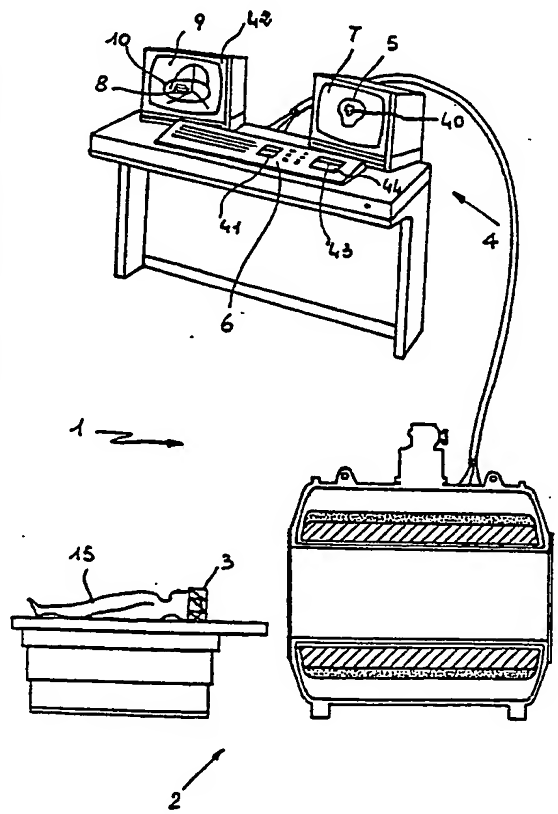
(54) Title: PROCESS AND APPARATUS PARTICULARLY FOR GUIDING NEUROSURGICAL OPERATIONS

(57) Abstract

The process for guiding neurosurgical operations allows to considerably reduce surgical traumatism during the removal of cerebral lesions by virtue of the possibility of converting into three-dimensional images both the contours of the anatomical structures and the representation of the device for the stereotaxic detection of the affected region together with a stereotaxic probe which defines a surgical path. The apparatus for executing the above mentioned process comprises means (4) for transferring two-dimensional radiological images (5) arriving from a CAT or MR device to a computer (6) which is equipped with a visual display and comprises processing means for converting the two-dimensional images into three-dimensional images (8) together with the schematic three-dimensional representation of the stereotaxic detection device (3).



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PROCESS AND APPARATUS PARTICULARLY FOR GUIDING NEUROSURGICAL OPERATIONS

TECHNICAL FIELD

The present invention relates to a process and apparatus particularly for guiding neurosurgical operations.

BACKGROUND ART

As is known, neuroradiological diagnostics has currently undergone an enormous development, especially with the introduction and use of devices such as CAT (computerized axial tomography) and MR (magnetic resonance) which can provide the surgeon with anatomical information in order to allow him to reach the lesion on the patient especially in the case of some kinds of endocranial lesions.

For these and other reasons, stereotaxic neurosurgical technique has developed considerably, since the execution of neuroradiological examinations in stereotaxic conditions allows to give each element of the radiographic image a precise orientation with respect to a preset operative reference system.

Such systems are mainly used especially with regard to cerebral lesions, but this does not mean that in the near future, with the development in the field of neurosurgical armamentarium, such systems might not be used effectively on any part of the human body.

Reference is therefore hereinafter made to neurosurgical operations, bearing in mind the non-limitation of use of the process according to the invention only to such operations.

In the case of cerebral lesions, since the encephalon is not subjected to significant modifications with respect to the braincase from the time of execution of the radiological examinations to the time of surgical intervention, it is possible to study and develop various possibilities of neurosurgical execution based on the different stereotaxic paths of approach to the cerebral lesions which the surgeon intends to use, according to the neuro-anatomical information acquired, as mentioned, by CAT or MR.

The use of CAT or MR currently allows to determine the coordinates of a lesion or of a neoplasm identified on the planar radiological image and therefore to determine the angles which define the so-called approach path, i.e. the preferred and best, though sometimes longer, direction followed by the surgeon during the actual operation.

The definition of the approach path with regard to the radiological image is currently generally performed by the surgeon at the diagnostic console with which the CAT or MR device is equipped.

By examining the various radiological images in succession (as regards CAT, by viewing in succession biplanar anatomical sections of the parallel sections or, as regards MR, by examining the semiaxial, frontal or sagittal planes), the surgeon must visualize the three-dimensional extension of the anatomical elements shown in the radiological images and therefore decide on the basis of his experience the surgical path to be followed during the operation so as to not damage the tissues adjacent to the lesion.

By means of this procedural method, which is currently in use, the surgeon is able to locate and reach with sufficient precision any neoplasm or part of the encephalon, but can never have such information as to allow him to plan the operation with absolute certainty.

This disadvantage arises from the fact that the axis of the path of the surgical probe which traverses the various anatomical elements in order to reach the lesion is not, in most cases, along one of the planes defined by the parallel sections of the CAT radiographs or of the semiaxial, frontal or sagittal planes of MR in which the anatomical image is represented.

This is why the three-dimensional reconstruction of the image is totally left to the visualization ability of the surgeon.

The surgeon therefore currently chooses a path of approach to the neoplasm by examining in succession the various sections provided by CAT and MR, but is unable to examine the complete volume of the lesion.

The problem becomes more severe if, for example, the purpose of the intervention is to place a pellet of a radioactive isotope for a curative treatment inside the lesion or if said lesion is to be removed.

Especially in such cases, but also in the case in which a simple bioptic sampling must be performed, with the current method it is difficult for the surgeon to be perfectly aware of the various interconnections occurring between the lesion and the healthy cerebral structures which surround it.

The difficulty of determining a theoretical path to

be followed during the operation in order to reach the required point of the lesion by examining in succession the various biplanar anatomical sections resulting from the images produced by CAT or MR is consequently imaginable.

In addition to the above, it is furthermore stressed that the various determinations of the anatomical data performed on different devices cannot be integrated into a single image since they are presented separate from one another on the different consoles of the devices which produced them.

By way of example, the known art does not allow to evaluate the information supplied by angiography, an examination of extreme diagnostic significance, simultaneously with the images provided by CAT or by MR, since the three-dimensional visualization of the cerebral vessels is not possible.

It is therefore practically impossible to determine the possible collision of a surgical path with the vascular structures.

DISCLOSURE OF THE INVENTION

The aim of the present invention is to eliminate the above described disadvantages by providing a process and an apparatus particularly for guiding neurosurgical operations which allow to considerably reduce surgical traumatism during the removal of lesions, for example cerebral ones, using stereotaxic methods guided by the anatomical reconstruction of images arriving from CAT or MR.

Within the scope of this aim, an important object of

the invention is to provide a process and apparatus particularly for guiding neurosurgical operations which allow to adopt surgical approach paths which avoid traumatism of the healthy tissue which surrounds even deep lesions by performing a surgical path which may sometimes be longer than what normally occurs for lesions proximate to the convexity of the braincase.

Another object of the present invention is to provide a process and apparatus particularly for guiding neurosurgical operations which allow to visualize in three dimensions, together with the lesion, the cerebral structures of surgical interest, especially the main vessels, the internal capsule and the nuclei, as well as the eloquent cortical regions.

Not least object of the present invention is to provide a process and apparatus particularly for guiding neurosurgical operations which allow to provide information on the orientation of the surgical instruments relative to the operative reference.

This aim, these objects and others are substantially achieved by a process and apparatus particularly for guiding neurosurgical operations, characterized in that it consists in: performing the required neuroradiological examinations, by means of at least one stereotaxic detection device, on a part of the patient; loading in the memory of a computer the radiological images arriving from a computerized axial tomography device or from a nuclear magnetic resonance device; storing in said computer the location of the reference points produced by said stereotaxic detection device on said radiological images;

detecting in said computer the contour of the different anatomical structures of each of said images; storing in said computer said contour of said different anatomical structures; processing, by means of a specific program, all the data entered into said computer to represent on a visual display a schematic three-dimensional image of said contours of said different anatomical structures of said images together with a schematic three-dimensional image of said stereotaxic detection device and of a stereotaxic probe which defines a surgical path.

Said process is performed by an apparatus particularly for guiding neurosurgical operations, comprising a computerized axial tomography device or a magnetic resonance device connected to a stereotaxic detection device, characterized in that it comprises: means for transferring two-dimensional radiological images arriving from said computerized axial tomograph device or from said magnetic resonance device to a computer equipped with a visual display, said computer comprising processing means for converting said two-dimensional radiological images into three-dimensional images on said visual display simultaneously with the schematic three-dimensional representation of said stereotaxic detection device.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the invention will become apparent from the description of a preferred but not exclusive embodiment of a process and apparatus particularly for guiding neurosurgical operations according to the invention, illustrated only by

way of non-limitative example in the accompanying drawings, wherein:

figure 1 is a schematic perspective view of the apparatus for guiding neurosurgical operations according to the invention;

figure 2 is a block diagram of the apparatus illustrated in figure 1;

figure 3 is an enlarged view of the three-dimensional image which is displayed on the visual display of the apparatus according to the invention;

figure 4 is a perspective view of the locator device according to the invention;

figure 5 is a schematic view of the projection of the reference points of the locator device on a stereoscopic projection obtained with a digital angiograph;

figure 6 is a view of the stereotaxic probe superimposed on two stereoscopic angiographic images; and

figure 7 is a schematic view of the articulated arm adapted to place the anatomical three-dimensional images in a univocal spatial relationship with the orientation of one or more surgical instruments.

WAYS OF CARRYING OUT THE INVENTION

With reference to the above described figures, the process according to the invention is provided by means of the following succession of steps.

A stereotaxic detection device, more precisely a stereotaxic helmet (3), is initially fitted onto the patient (15) in order to subject him to the preparatory neuroradiological examinations before surgery.

The stereotaxic helmet comprises a locator element

(16) by means of which it is possible to detect and identify the arrangement of the plane of the image in relation to the operative reference constituted by said stereotaxic helmet.

The use of stereotaxic helmets made of a material suitable for being shown by neuroradiological examinations without distorting or masking the image, conveniently allows to univocally and precisely determine a plurality of references, and it is possible to determine the position of the plane of the radiological image according to the positioning of said references.

The radiographic images thus obtained by MR or CAT, by means of the use of the stereotaxic helmet, are fed into the computer (6) and loaded into memory to be then displayed on the display of said computer.

Once the computer has acquired the arrangement of the sectional plane of each radiographic image arriving from CAT or MR, the operator, and more precisely the surgeon, can trace the contour of the anatomical structures (40) which occur on each section and are, in his opinion, relevant for the planning of the operation.

The limits of the pathological tissue, the position of the ventricles, the main vessels and the eloquent cerebral areas are generally determined.

This detection of the contour of the anatomical structures occurring in each radiographic image is performed for example manually by the surgeon, using a cursor driven by a digitizer pad (43), naturally after the specifications of the type of stereotaxic helmet used for the detection of the neuroradiological tests performed on

CAT or on MR has been fed into the computer.

The above described procedure is repeated by the surgeon for each radiological image of CAT or MR, and an identical color is assigned to the contours which belong to the anatomical structure related to a same kind of tissue, so as to facilitate the identification of the various tissues even if they mutually interpenetrate.

When all the information has been acquired by the computer, the computer is capable, by means of a particular program, of displaying on the display a three-dimensional schematic image of the stereotaxic helmet and of a stereotaxic probe 21 which defines the surgical path chosen by the surgeon to perform the actual operation.

The various contours of the anatomical structures of the radiological images, which had been previously determined by the surgeon, as previously specified, are simultaneously reproduced in three dimensions inside the diagram defined by the schematic representation of the stereotaxic helmet, and areas intended to control the rotation of the image and the orientation of the stereotaxic probe are displayed in the peripheral part of the visual display.

Finally, the angle (42) and depth values, which correspond, on the helmet used during surgery, to the path defined by the stereotaxic probe chosen by the surgeon on the visual display for the approach to the operation, are also indicated on the visual display.

In an alternative solution, an articulated arm, indicated by 30, having at least six degrees of freedom and position detectors 31 associated with the regions

where its configuration changes, can be used to give the computer the orientation of the arm with respect to the stereotaxic helmet 3 with which said arm is associated in a preset manner by means of the feet 32.

By means of the articulated arm it is possible to arrange the three-dimensional anatomical images 8 in univocal spatial relationship with the orientation of one or more known surgical instruments, not illustrated in the drawings, which are orientated by the surgeon during the operation.

More in detail, the articulated arm is rotatably associated with an annular base plate 33 which, as already mentioned, is associated with the stereotaxic helmet 3 by means of the feet 32.

The first rod-like element 34 of the arm is telescopingly extendable and rotatably supports a second rod-like element 35 which is also telescopingly extendable and in turn articulately supports a third rod-like element 36 adapted to receive on its free end one or more surgical instruments.

As regards the conversion of the cerebral angiographic radiological images into three-dimensional images, the process according to the invention is performed according to the following succession of steps.

The stereotaxic helmet, arranged in the identical position in which CAT and MR were performed, is initially positioned so that it is in the isocenter of rotation of the cathode-ray tube of a conventional digital angiograph.

In this manner a series of image acquisitions is performed according to defined stereoscopic projections.

A locator device 16 is furthermore associated with the stereotaxic helmet and comprises a ring 20 from which three rods 17 extend perpendicular to the plane of said ring, each of said rods being tipped by a small steel sphere 18.

The three rods are conveniently spaced from one another on the perimeter of the ring and have a mutually different height from the plane of the helmet, so as to not mutually superimpose in the different angles and project images in different positions on the stereoscopic angiographic sequences illustrated in figures 5 and 6.

In a preferred technical solution, the images thus obtained are digitized by means of a TV camera and transferred to the surgical graphic computer.

At this point the surgeon, using the cursor of a digitizer pad, can identify in each image the exact position of the three spheres and therefore the angle of acquisition of the angiographic image.

By virtue of the above, since the distances between the focus of the cathode-ray tube, the stereotaxic helmet and the plane of the image and obviously the arrangement of the stereotaxic helmet in the plane of rotation of the cathode-ray tube of the digital angiograph are fixed and known, it is possible to univocally determine the angle of acquisition of each angiographic projection.

At this stage it is possible, by means of the computer, to calculate the projection of a stereotaxic path in relation to each angle of acquisition of each angiographic projection and thus superimpose it on each of the stereotaxically acquired angiographic images.

At this point the surgeon can determine the optimum surgical path by using the information detected by CAT or MR and obtain the projection of the chosen path 21 on the stereotaxically acquired angiographic images.

From what has been described, the simultaneous observation of two stereoscopic images, by means of appropriate glasses, allows the three-dimensional perception of the mutual relationships between the vascular structures and the surgical probe.

Obviously, if the surgical target is a vascular structure, the entire planning of the operation will be performed exclusively on the angiographic images.

As previously mentioned, the apparatus for guiding neurosurgical operations, generally indicated by the reference numeral 1, comprises a computerized axial tomography device or, as illustrated in figure 1, a magnetic resonance device 2 connected to a stereotaxic detection device, such as a known stereotaxic helmet 3 worn by a patient 15.

The apparatus 1 comprises means 4 for transferring the two-dimensional radiological images 5, arriving for example from the MR, to a computer 6 equipped with a visual display 7.

The computer 6 comprises in turn processing means, and more in detail software adapted to convert the two-dimensional images 5 into three-dimensional images 8 which are visible on a visual display 9 together with the three-dimensional schematic representation 10 of the stereotaxic helmet.

The apparatus for performing the three-dimensional

processing of the cerebral angiographic images comprises a known digital angiograph, not illustrated in the drawings, in which the stereotaxic helmet 3 worn by the patient 15 is placed exactly at the isocenter of rotation of the cathode-ray tube.

A locator device 16 can furthermore be removably associated on the stereotaxic helmet and has three rods 17 tipped by small steel spheres 18 which are appropriately spaced and mounted at a different height from the plane of the helmet.

The invention thus conceived is susceptible to numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may furthermore be replaced with technically equivalent elements.

In practice, the materials employed, as well as the dimensions, may be any according to the requirements and to the state of the art.

CLAIMS

1. Process particularly for guiding neurosurgical operations, characterized in that it consists in: performing the required neuroradiological examinations by means of at least one stereotaxic detection device (3) on a part of a patient (15); loading in the memory of a computer (6) the radiological images (5) arriving from a computerized axial tomography device and/or from a nuclear magnetic resonance device; storing in said computer the location of the reference points (18) produced by said stereotaxic detection device on said radiological images; detecting in said computer the contour of the different anatomical structures (40) of each of said images; storing in said computer said contour of said different anatomical structures; processing, by means of a specific program, all the data entered into said computer in order to represent on a visual display (9) a schematic three-dimensional image (8) of said contours of said different anatomical structures of said images together with a schematic three-dimensional image (10) of said stereotaxic detection device and of a stereotaxic probe (21) which defines a surgical path.

2. Process according to claim 1, characterized in that said computer is accommodated in the immediate neighborhood of the operating room where the surgical operation is performed on said patient.

3. Process according to claim 1, characterized in that said stereotaxic detection device (3) comprises a locator element (16) for detecting the position of at

least one surgical instrument relative to said radiological images in relation to said stereotaxic detection device.

4. Process according to claim 3, characterized in that said locator element comprises an articulated arm (30) which is rotatably associated with an annular base plate (33) which has feet (32) for associating it with said stereotaxic detection device (3) in a preset manner.

5. Process according to claim 4, characterized in that said articulated arm has a first rod-like element (34) which is rotatably associated with a second rod-like element (35) which in turn rotatably supports a third rod-like element (36) for supporting surgical instruments, said arm having position detectors (31) associated with the regions in which its configuration varies.

6. Process according to claim 5, characterized in that at least one of said first and second rod-like elements is telescopingly extendable.

7. Process according to claim 1, characterized in that the storage of said contour of said different anatomical structures, arriving from said computerized axial tomography device and/or from said nuclear magnetic detection device, in said computer is performed manually by moving a cursor (43) on a digitizer pad (44).

8. Process according to claim 1, characterized in that said contour of said different anatomical structures of said radiological images has an identical coloring for each kind of tissue.

9. Process according to claim 1, characterized in that said visual display has control means (41) for

rotating said first three-dimensional image and for orientating said surgical path relatively thereto.

10. Process according to claim 1, characterized in that said visual display has indications of angle values (42) and of the depth of said surgical path which correspond to equivalent angular values of an operative guiding device.

11. Apparatus particularly for guiding neurosurgical operations, comprising a computerized axial tomography device or a magnetic resonance device (2) connected to a stereotaxic detection device (3), characterized in that it comprises means (4) for transferring two-dimensional radiological images (5) arriving from said computerized axial tomography device or from said magnetic resonance device to a computer (6) equipped with a visual display (9), said computer comprising processing means for converting said two-dimensional radiological images into three-dimensional images (8) on said visual display (9) and for the schematic three-dimensional representation of said stereotaxic detection device.

12. Apparatus according to claim 11, characterized in that it comprises a digitizer pad (43) for interaction with said three-dimensional images on the part of an operator.

13. Process particularly for guiding neurosurgical operations, characterized in that it consists in: applying a stereotaxic helmet (3) on a patient; associating with said stereotaxic helmet a locator device (16); performing a series of stereotaxic acquisitions according to stereoscopic projections defined by means of a digital

angiograph; projecting onto each of said stereoscopic projections a plurality of reference points (18) of said locator device; storing said stereotaxic acquisitions in a computer (6); identifying said reference points in each stereoscopic angiographic image; univocally determining the angle of acquisition of each angiographic projection; calculating the projection of a stereotaxic path for each of said acquisition angles; superimposing said projection onto said angiographic image.

14. Process according to claim 13, characterized in that said stereotaxic helmet and said locator device are arranged in the isocenter of rotation of the cathode-ray tube of said digital angiograph.

15. Process according to claim 13, characterized in that said locator device comprises an annular element (20) from which at least three rods (17) extend perpendicularly, each rod having a sphere (18) at its end.

16. Process according to claim 13, characterized in that said rods are mutually spaced along the perimeter of said ring and have mutually different heights.

17. Process and apparatus particularly for guiding neurosurgical operations, characterized in that they comprise one or more of the described and/or illustrated characteristics.

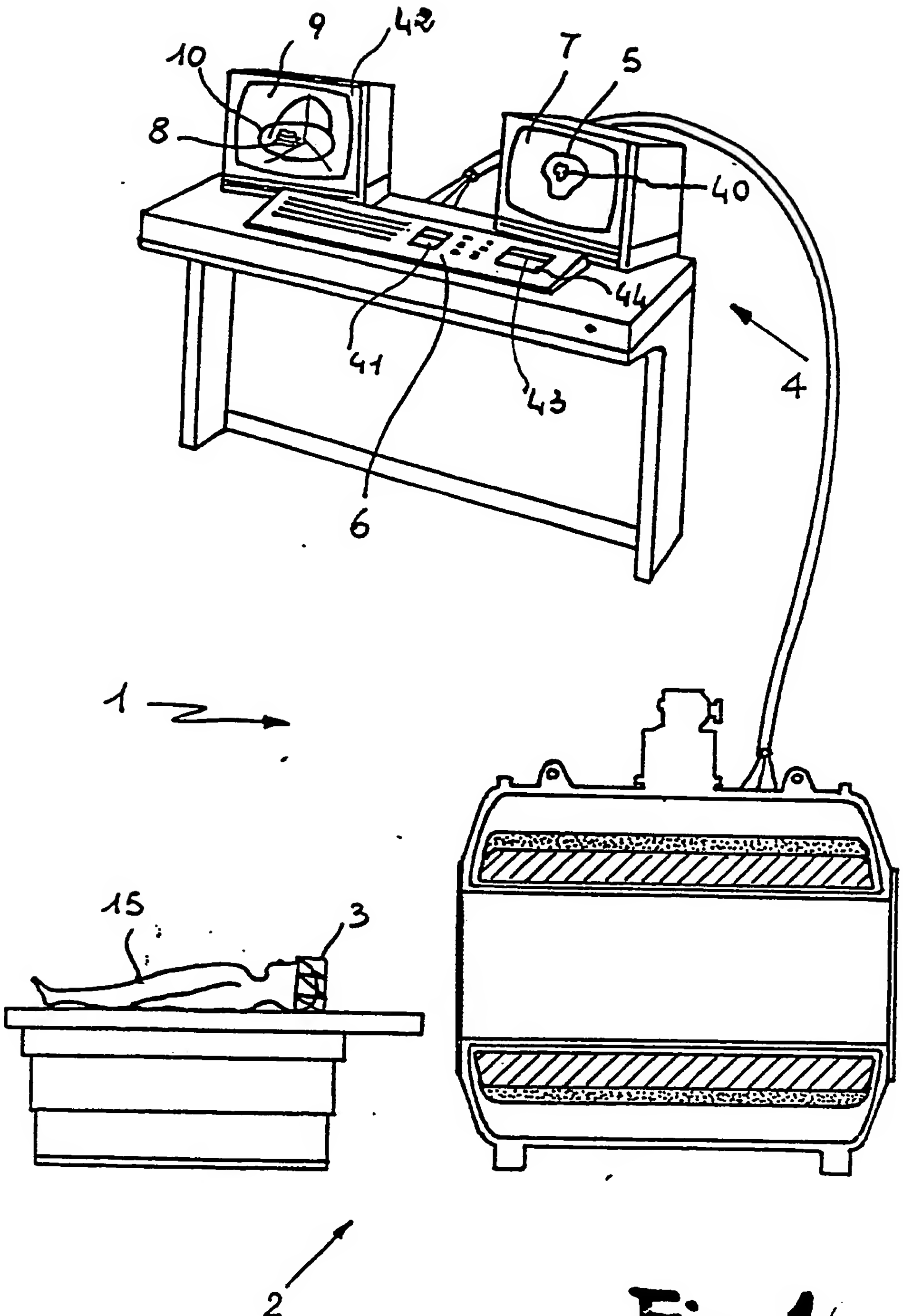

Fig. 1

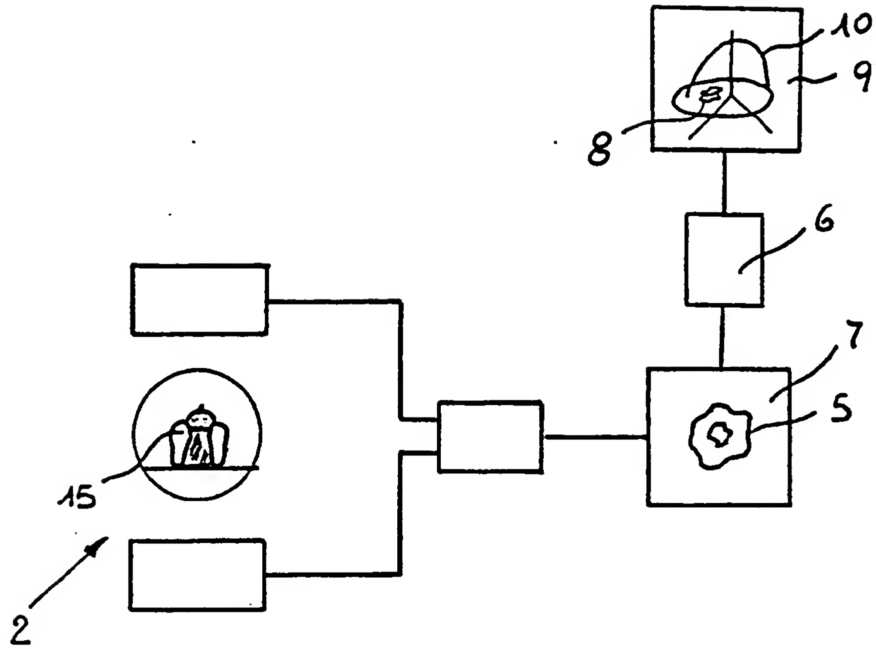

Fig. 2

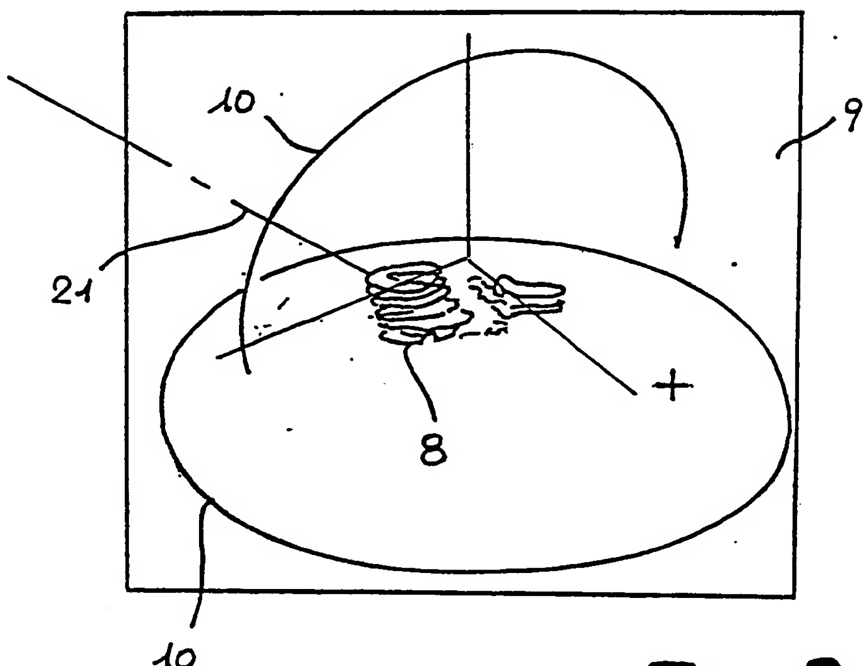

Fig. 3

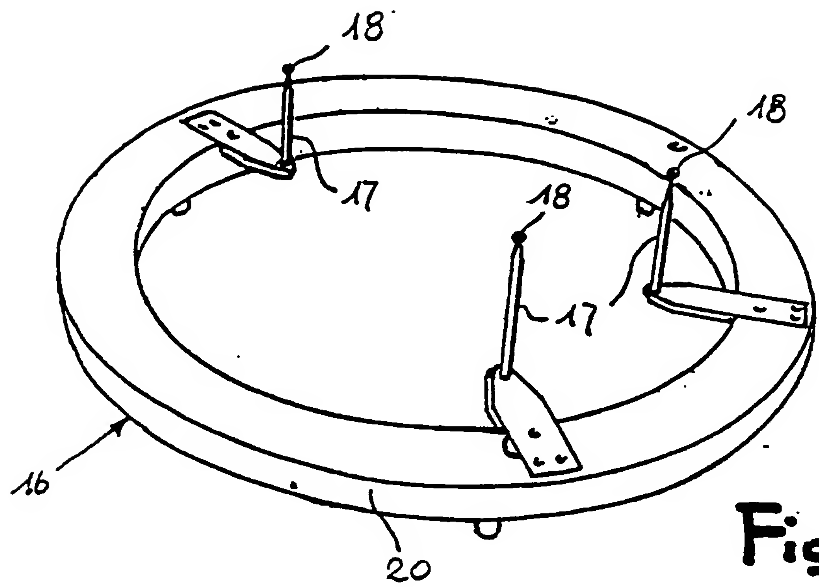

Fig.4

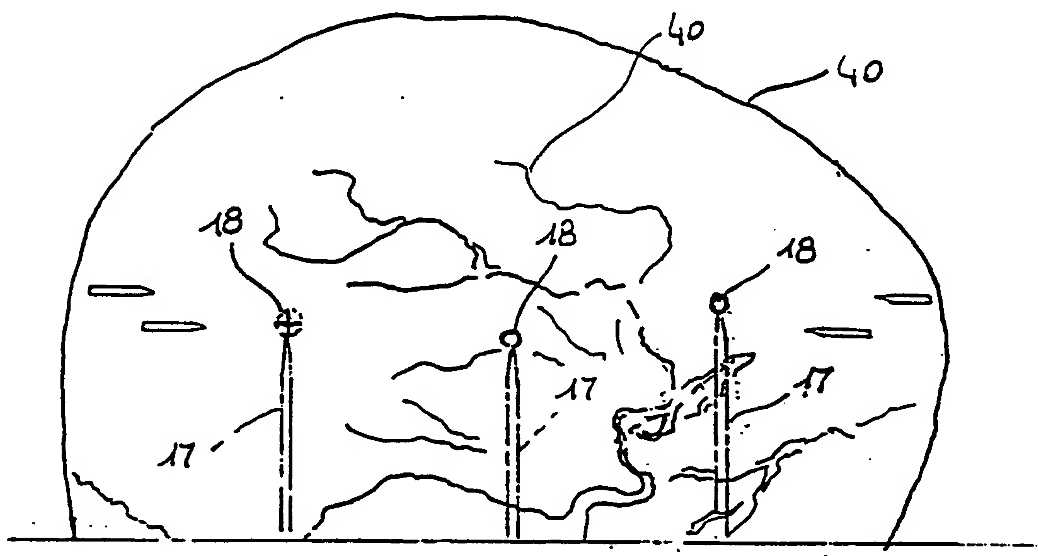

Fig.5

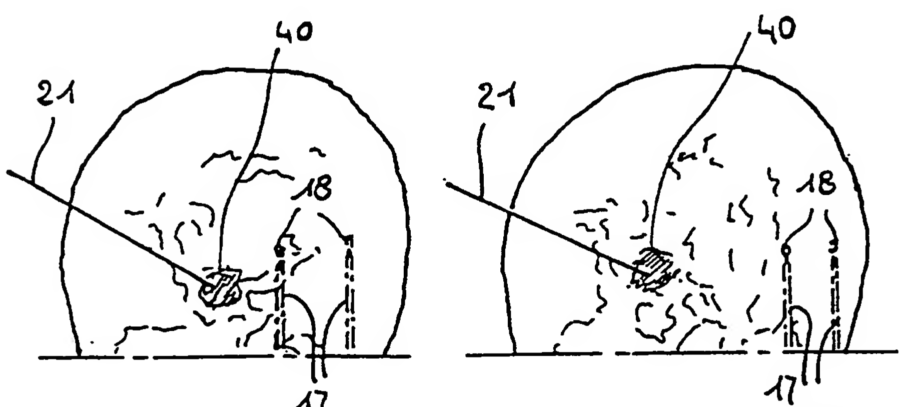

Fig.6

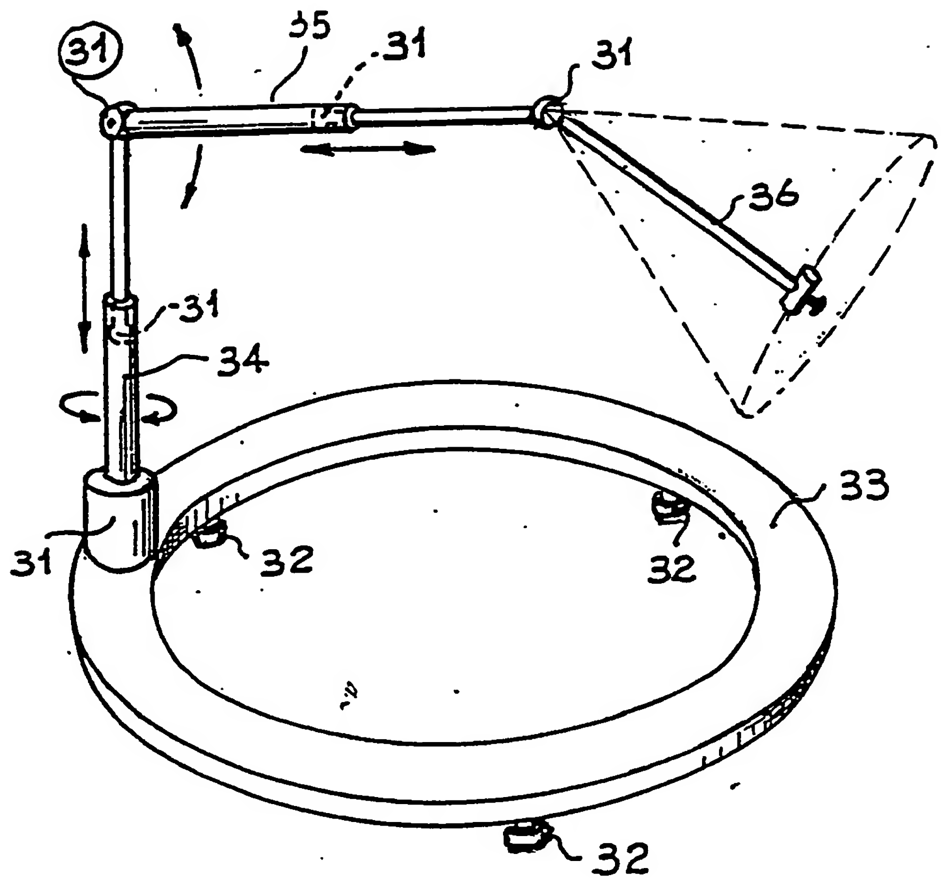

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No PCT/EP 89/01362

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^5: A 61 B 19/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^5	A 61 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4638798 (SHELDEN et al.) 27 January 1987 see column 4, line 64 - column 5, line 15; column 6, lines 13-35; column 7, lines 42-50; column 9, lines 33-50; column 12, lines 28-35; figures 3,4,9 --	1-3,7-17
A	US, A, 4465069 (BARBIER et al.) 14 August 1984 see column 5, lines 5-20; figure 1	3-6

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
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EUROPEAN PATENT OFFICE	T.K. WILLIS

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EP 8901362
SA 32234

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4638798	27-01-87	None	
US-A- 4465069	14-08-84	None	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82